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Our reference: GC-122.3-US-U1

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Larry Coldren et al
Serial Number: unknown
Filing Date: June 11, 2001
Examiner/Group Art Unit: unknown
Title: IMPROVED MANUFACTURABLE
SAMPLED GRATING MIRRORS

Commissioner of Patents and Trademarks
Box New Application
Washington, DC 20231

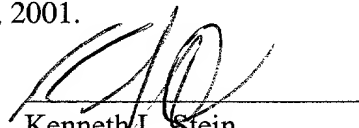
CERTIFICATE OF MAILING AND TRANSMITTAL LETTER

Sir:

Transmitted herewith is this certificate of mailing (in duplicate), an original patent application have 13 pages including a specification, claims and abstract, and eight (8) figures on six (6) sheets of drawings, a declaration and declaration of small business entity and power of attorney, and a STAMPED, SELF-ADDRESSED RETURN POSTCARD in the above identified application.

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Agility Communications, Inc.
600 Pine Avenue
Santa Barbara, CA 93117
Dated: June 11, 2001
Express Mailing Number: ET103178994US

09879821-06-11-01

Patent Application

for:

IMPROVED, MANUFACTURABLE SAMPLED GRATING MIRRORS

Inventors:

Gregory A. Fish and Larry A. Coldren

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T.D.T.90.7.29.6.85.0

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. Section 119(e) of the following co-pending and commonly-assigned U.S. provisional patent application: Serial No. 60/210,612, filed June 9, 2000, by Gregory A. Fish and Larry A. Coldren, entitled "IMPROVED, MANUFACTURABLE SAMPLED GRATING MIRRORS," attorneys' docket number 122.3-US-P1, which application is incorporated by reference herein.

This application is related to the following co-pending and commonly-assigned U.S. utility patent applications:

Serial No. 09/614,224, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "METHOD OF MAKING A TUNABLE LASER SOURCE WITH INTEGRATED OPTICAL AMPLIFIER";

Serial No. 09/614,377, filed July, 12, 2000, by Larry A. Coldren, and entitled "INTEGRATED OPTO-ELECTRONIC WAVELENGTH CONVERTER ASSEMBLY";

Serial No. 09/614,376, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "METHOD OF CONVERTING AN OPTICAL WAVELENGTH WITH AN OPTO-ELECTRONIC LASER WITH INTEGRATED MODULATOR";

Serial No. 09/614,378, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "OPTO-ELECTRONIC LASER WITH INTEGRATED MODULATOR";

Serial No. 09/614,895, filed July, 12, 2000, by Larry A. Coldren, and entitled "METHOD FOR CONVERTING AN OPTICAL WAVELENGTH USING A MONOLITHIC WAVELENGTH CONVERTER ASSEMBLY";

Serial No. 09/614,375, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "TUNABLE LASER SOURCE WITH INTEGRATED OPTICAL AMPLIFIER";

Serial No. 09/614,195, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "METHOD OF MAKING AND OPTO-ELECTRONIC LASER WITH INTEGRATED MODULATOR";

Serial No. 09/614,665, filed July, 12, 2000, by Larry A. Coldren et al., and entitled "METHOD OF GENERATING AN OPTICAL SIGNAL WITH A TUNABLE LASER SOURCE WITH INTEGRATED OPTICAL AMPLIFIER"; and

Serial No. 09/614, 674, filed July, 12, 2000, by Larry A. Coldren, and entitled "METHOD FOR MAKING A MONOLITHIC WAVELENGTH CONVERTER ASSEMBLY";

all of which are incorporated by reference herein, all of which claim priority to each other, and all of which claims the benefit under 35 U.S.C. §119(e) to the following U.S. provisional patent applications:

Serial No. 60/152,038, filed on September 2, 1999, by Gregory Fish et al., and entitled "OPTOELECTRONIC LASER WITH INTEGRATED MODULATOR";

Serial No. 60/152,049, filed on September 2, 1999, by Larry Coldren, and entitled "INTEGRATED OPTOELECTRONIC WAVELENGTH CONVERTER"; and

Serial No. 60/152,072, filed on September 2, 1999, by Beck Mason et al., and entitled "TUNABLE LASER SOURCE WITH INTEGRATED OPTICAL AMPLIFIER".

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates generally to wide-range tunable semiconductor lasers and particularly to sampled-grating distributed Bragg reflector (SGDBR) lasers. More particularly, this invention relates to an improved design for sampled grating distributed Bragg reflector (DBR) mirrors.

2. Description of the Related Art.

Diode lasers are being used in such applications as optical communications, sensors and computer systems. In such applications, it is very useful to employ lasers that can be easily adjusted to output frequencies across a wide wavelength range. A diode laser which can be operated at selectably variable frequencies covering a wide wavelength range, i.e. a widely tunable laser, is an invaluable tool. Such a "widely-tunable" laser enables real-time provisioning of bandwidth, and a much simplified sparing scheme. By including widely-tunable lasers in a system, if one laser malfunctions, a spare channel, purposely left unused, may be configured to the wavelength of the malfunctioning laser and ensure the proper function of the system.

Thus, while diode lasers have provided solutions to many problems in communications, sensors and computer system designs, they have not fulfilled their potential based on the available bandwidth afforded by light-based systems. It is important that the number of channels be accessed and switched between in order for optical systems to be realized for many future applications.

For a variety of applications, it is necessary to have tunable single-frequency diode lasers which can be quickly configured to emit coherent light at any of a wide range of wavelengths. Such applications include sources and local oscillators in coherent lightwave communications systems, sources for other multi-channel lightwave communication systems, and sources for use in frequency modulated sensor systems. Continuous tunability is usually needed over some range of wavelengths. Continuous tuning is important for wavelength locking or stabilization with respect to some other reference, and it is desirable in certain frequency shift keying modulation schemes.

In addition, widely tunable semiconductor lasers, such as a sampled-grating distributed-Bragg-reflector (SGDBR) laser, a grating-coupled sampled-reflector (GCSR) laser, and vertical-cavity surface emitting lasers with micro-electromechanical moveable mirrors (VCSEL-MEMs) generally must compromise their output power in order to achieve a large tuning range. Designs that can provide over 40 nm of tuning range have not been able to provide much more than a couple of milliwatts of power out at the extrema of their tuning spectrum. However, current and future optical fiber communication systems as well as spectroscopic applications require output powers in excess of 10 mW over the full tuning band. Current ITU bands are about 40 nm wide near 1.55 μm and comprise the c-band, s-band and L-band, and it is desired to have a single component that can cover at least one or more of these bands.

Systems that are to operate at higher bit rates may require more than 20 mW over the full ITU bands. Such powers are available from DFB lasers, but these can only be tuned by a couple of nanometers by adjusting their temperature. Thus, it is very desirable to have a source with both wide tuning range (> 40 nm) and high power (> 10 mW) without a significant increase in fabrication complexity over existing widely tunable designs.

One path to achieving high output power and wide tuning ranges, is to improve upon the conventional sampled grating mirrors or reflectors (which shall be used interchangeably hereinbelow). Figure 1 shows a typical reflectivity spectrum from a pair of mirrors used within a SG-DBR laser. The design of the SG-DBR is constrained by the desired tuning range, output power and side-mode suppression. It is impossible to simultaneously maximize all three of the above specifications using a SG-DBR, as improving one specification worsens the others. The major concerns when designing a multi-peaked mirror are to achieve the desired coupling constant (κ) and reflectivity (R) for each peak.

The sampled grating approach is limited largely by the fact that the unsampled grating κ is technologically limited by optical scattering to around 300 cm^{-1} . Another limiting factor is that the reflectivity of the multi-peaked mirror falls off at the outer peaks, along with the gain. Therefore, it is desirable to increase the effective κ of each peak as well as compensate for any loss in gain with increased reflectivity. In order to increase the κ of the SG mirror peaks, the sampling duty ratio (the length of sampled portion divided by the sampling period) must also increase. This duty ratio, however, is inversely proportional to the wavelength range the multi-peaked SG mirror can effectively cover, which limits the tuning range of a SG-DBR laser.

Therefore, what is needed in the art is a sampled grating mirror that covers a wide tuning range with the desired κ , as well as having mirror peaks that do not have substantial power dorpofts at the edges of the band.

SUMMARY OF THE INVENTION

To address the issues described hereinabove, enhanced sampled-grating distributed Bragg reflector (SGDBR) mirrors are disclosed and taught in accordance with the present invention. The major concerns when designing a SGDBR or multi-peaked mirror are to achieve the desired coupling constant (κ) and reflectivity (R) for each peak. The explicit details of the mirror design with respect to these values are described in U.S. Patent No. 4,896,325, issued January 23, 1990, to Larry A. Coldren, entitled "MULTI-SECTION

TUNABLE LASER WITH DIFFERING MULTI-ELEMENT MIRRORS”, which patent is incorporated by reference herein.

Several references describe structures and methods for achieving wide tuning ranges. These references include:

V. Jayaraman, A. Mathur, L.A. Coldren and P.D. Dapkus, “Theory, Design, and Performance of Extended Tuning Range in Sampled Grating DBR Lasers,” *IEEE J. Quantum Elec.*, v. 29, (no. 6), pp. 1824-1834, (June 1993);

H. Ishii, H. Tanobe, F. Kano, Y. Tohmori, Y. Kondo, Y. Yoshikuni, “Quasicontinuous Wavelength Tuning in Super-Structure-Grating (SSG) DBR Lasers”, *IEEE J. Quantum Elec.*, v. 32, (no. 3), pp. 433-441, (March 1996);

I. Avrutsky, D. Ellis, A. Tager, H. Anis, and J. Xu. “Design of Widely Tunable Semiconductor Lasers and the Concept of Binary Superimposed Gratings (BSG’s)”, *IEEE J. Quantum Elec.*, v. 34, (no. 4), pp. 729-741, (April 1998);

B. Mason, G.A. Fish, S.P. DenBaars, and L.A. Coldren, “Widely Tunable Sampled Grating DBR Laser with Integrated Electroabsorption Modulator,” *Photon. Tech. Letts.*, 11, (6), 638-640, (June 1999); and

Tennant, D.M., Koch, T.L., Verdiell, J.-M., Feder, K., Gnall, R.P., Koren, U., Young, M.G., Miller, B.I., Newkirk, M.A., Tell, B., *Journal of Vacuum Science & Technology B* vol.11, (no.6), Nov.-Dec. 1993. p.2509-13.

Each of the proceeding references are incorporated herein by reference, however, they fail to teach or suggest the present invention.

The present invention comprises a specially configured DBR mirror. And such a mirror may be included in a tunable laser. The tunable laser generally comprises a gain section for creating a light beam by spontaneous emission over a bandwidth, a phase section for controlling the light beam around a center frequency of the bandwidth, a waveguide for guiding and reflecting the light beam in a cavity, a front mirror bounding an end of the cavity and a back mirror bounding an opposite end of the cavity wherein gain is provided by at least one of the group comprising the phase section, the front mirror and the back mirror.

This invention relates to the tailoring the reflectivity spectrum of a SGDBR by applying digital sampling theory to choose the way each mirror is sampled. The resulting

mirror covers a larger wavelength span and has peaks with a larger, more uniform, coupling constant (κ) than the mirrors produced using conventional approaches. The improved mirror also retains the benefits of the sample grating approach. These embellishments on the SGDBR design provide devices that meet the higher power goals with wide tuning. In addition, most of the embodiments are relatively simple to manufacture.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

Fig. 1 Shows a schematic of a SG-DBR laser illustrating the use of two sampled grating reflectors to form the laser resonator containing a gain and phase shift region.

Fig. 2 illustrates the typical reflectivity spectrum of a sampled-grating mirror showing the multiple peaks and the decrease of the reflectivity at the edges of the spectrum.

Fig. 3 (a) & (b) illustrates a schematic diagram and the mathematical representation of the sampled grating reflector. The representation can be thought of the multiplication of grating function and a sampling function.

Fig. 4 gives an example of a very simple modification to the conventional grating that could be used to tailor the envelope of the peak mirror reflectivities, in which a burst of anti-phased grating is positioned properly in front of the 1st burst of the conventional grating.

Fig. 5 shows a simulation illustrating the effect of the adding a single anti-phased burst to a conventional sampled grating DBR. Proper positioning of the anti-phased burst can be used to flatten or modify the conventional spectra.

Fig. 6 illustrates a manipulation of the sampling function that leads to a more desirable multi-peaked sampled-grating reflector, by reversing the phase of the sampling function at the beginning and end of each burst.

Fig. 7 (a) & (b) illustrate an example of using the modified sampling function to give a wider wavelength range than the conventional sampling function.

Fig. 8 (a) & (b) illustrates an example of using the modified sampling function to give an increase in the κ of the sampled grating mirror over the same wavelength range as the conventional sampling function.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, reference is made to the accompanying drawings which form a part hereof, and in which is shown, by way of illustration, an embodiment of the present invention. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Figure 2 depicts a widely-tunable, four-section SG-DBR laser 10 that makes use of two multi-peaked DBR mirrors 12,14, which are formed and configured in accordance with the present invention, to achieve an extended tuning range. Currents are applied to the various electrodes to provide a desired output optical power and wavelength as discussed in US Patent #4,896,325. As described therein, a current to the gain section 16 creates light and provides gain to overcome losses in the laser cavity; currents to the two differing SG-DBR wavelength-selective mirrors 12,14 are used to tune a net low-loss window across a wide wavelength range to select a given mode; and a current to a phase section 18 provides for a fine tuning of the mode wavelength. It should also be understood that the sections 12,14,16,18 are somewhat interactive, so that currents to any will have some effect on the parameters primarily controlled by the others.

An example of the mirror spectra from a conventional pair of mirrors, without the improved configuration, is shown in Figure 2. Mathematically, the sampled grating can be thought of as the multiplication of a grating function and a sampling function, as illustrated in Figure 3a and 3b. In the conventional design, the sampling function can only have the value of +1 or 0, due to the technological method used in fabrication. The grating function is also technologically limited to κ 's less than 300 cm^{-1} , to prevent optical scattering.

Examining Figure 3, the Fourier transform relation between the square sampling function of the conventional SG mirror and its sinc function envelope of reflectivity peaks is clearly obvious. Modification of the sampling function to tailor the frequency response of

the peak envelope is well known to those skilled in the art. In the case of the SG-DBR to be produced with a phase mask, the sampling function can only take the value of 0,1 or -1 , with -1 indicating a phase reversal of the grating function.

The phase mask technology for printing gratings, allows the sampling function to take on a value of $+1$, 0 and -1 , with a manufacturable process that can be used to create sampled grating. Phase masking is well known to those skilled in the art, although this application is new. This invention relates to using this added degree of freedom offered by current phase masking technology to tailor the spectrum of the SG-DBR wavelength-selective mirrors to improve the laser performance.

An embodiment of this invention can be as simple as adding a single anti-phased burst at the beginning of the grating as shown in Figure 4. Properly positioned, this burst can flatten the multi-peaked reflectivity spectrum, or make the reflectivity larger at the edges, as shown in Figure 5. These examples are very simple, and more sophisticated tailoring can be achieved identifying the analog sampling function that produces the desired effect and digitizing it using the strategies commonly employed in digital sampling applications.

Another sampling function is shown in Figure 6. Reversing the phase of the grating at the beginning and end of each sample can be used to tailor the peak envelope to allow for higher κ over a larger range. Figures 7a and 7b illustrate an example of the peak envelopes that would result from the modification discussed in Figure 6, showing that the modification produces the intended effect: a mirror with a wider wavelength range **and** with a larger κ throughout.

Figures 8a and 8b show a similar application of the sampling function that produces a mirror with twice the κ over the same tuning range with a much flatter envelope. A more sophisticated and powerful embodiment is to use the phase mask capability to tailor the sampling function to achieve the desired mirror peak spectrum.

Figures 7 and 8 show specific modifications to the sampling function used to create sampled-grating mirrors that cover a larger wavelength range and have higher reflectivity than the conventional approach. However, those skilled in the art can manipulate the sampling function within the constraints of the phase mask technology to produce a wide

range of desirable changes to the conventional approach. Additionally, as phase masking technology improves, the precision with which one may refine the sampling function will improve as well.

A method to select the configuration of a mirror 12,14 and therefore an associated sampling function, is to a) select a preferred κ for the wavelengths of a specific region of the band(s) that are to be used, b) select a preferred tuning range, c) using a sampling function that, when applied to the laser's output, results in the closest fit to the desired κ and output powers.

It is important to realize that one of the advantages of the sampled grating mirrors is that the areas without grating are technologically easier to produce with high tuning efficiency and reliability, as they have no etch damage and less exposed surface area. Therefore, it is desirable that the grating areas (regardless of its phase) occupy only a fraction of the entire mirror.

There are several advantages of this invention over the mirrors disclosed in the prior art. One of the biggest advantages is that the phase between the sampling function and the grating function need not be preserved, allowing the required phase mask to be fabricated with simply holography. In addition, all of the other methods accomplish the peak tailoring through the use of a modified grating that covers the entire surface of the waveguide, whereas this invention preserves the fact that the grating occupies less than 30% of the entire SG mirror. This is very important because it has a direct impact on the tuning efficiency of the mirror. During the fabrication of multi-peaked mirrors the process introduces crystal damage in the grating due to both etching and regrowth. This crystal damage reduces both tuning efficiency and lifetime of the widely tunable laser using these mirrors. It is much easier to produce a damage free surface in waveguide areas without grating, and SG-DBR's were shown to have superior tuning performance over other forms of widely tunable lasers with continuous gratings. Therefore, using the sampling function approach to modify the mirror spectrum is advantageous.

The foregoing description of one or more embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

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WHAT IS CLAIMED IS:

- 1 1. An improved distributed Bragg reflector comprising:
2 a first portion comprising a first phase;
3 at least a second portion spaced apart from said first portion comprising a
4 second phase, said phase being different from the first phase.
5
- 1 2. The reflector of claim 1, wherein the second portion has a second phase
2 opposite that of said first phase of said first portion .
- 1 3. The reflector of claim 1, wherein said spaced apart first portion and second
2 portion are configured to maximize the coupling constant (κ) as evenly as possible across a
3 selected tuning range.
- 1 4. A method for configuring a selected grating distributed Bragg reflector for
2 use in a laser having an output within a specific region of bandwidth, the method comprising
3 the steps of:
4 a) selecting a preferred κ for at least one wavelength of the specific region of
5 the bandwidth that is to be used;
6 b) selecting a preferred tuning range for said reflector;
7 c) generating a sampling function that, when applied to the reflector, results
8 in the closest fit to the desired average κ with the smallest amount of variation within the
9 selected tuning range.
- 1 5. A method for configuring a selected grating distributed Bragg reflector for
2 use in a laser having an output comprising at least one wavelength within a specific region of
3 bandwidth, the method comprising the steps of:
4 a) selecting a preferred tuning range for said reflector;
5 b) determining an average κ for the at least one output wavelength of the
6 specific region of the bandwidth that is to be used;

7 c) generating a sampling function that, when applied to the reflector, results
8 in the closest fit to the desired average κ with the smallest amount of variation within the
9 preferred tuning range.

1 6. The method of claim 5, wherein the at least one wavelength is a plurality of
2 wavelengths.

1 7. The method of claim 5, further comprising the step of sampling the reflector
2 in accordance with the sampling function.

1 8. The method of claim 4, wherein the at least one wavelength is a plurality of
2 wavelengths.

1 9. The method of claim 4, wherein the at least one wavelength is a plurality of
2 wavelengths.

1 10. The method of claim 4, further comprising the step of sampling the reflector
2 in accordance with the sampling function.

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ABSTRACT OF THE DISCLOSURE

The present invention relates to the tailoring the reflectivity spectrum of a SGDBR by applying digital sampling theory to choose the way each reflector is sampled. The resulting mirror covers a larger wavelength span and has peaks with a larger, more uniform, coupling constant (κ) than the mirrors produced using conventional approaches. The improved mirror also retains the benefits of the sample grating approach. Additionally, most of the embodiments are relatively simple to manufacture.

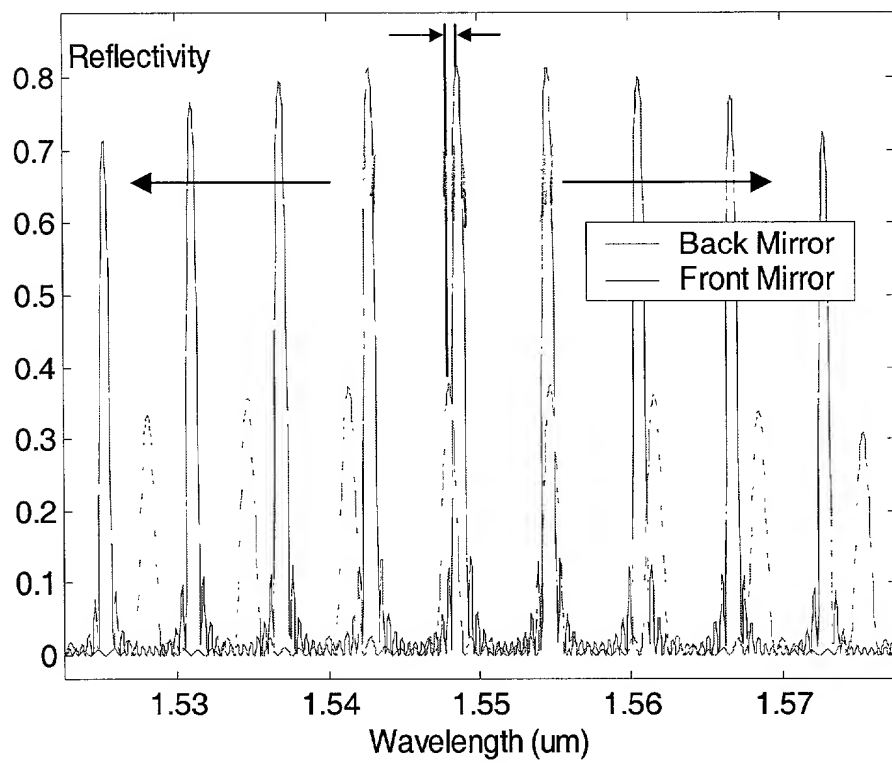


Fig. 1

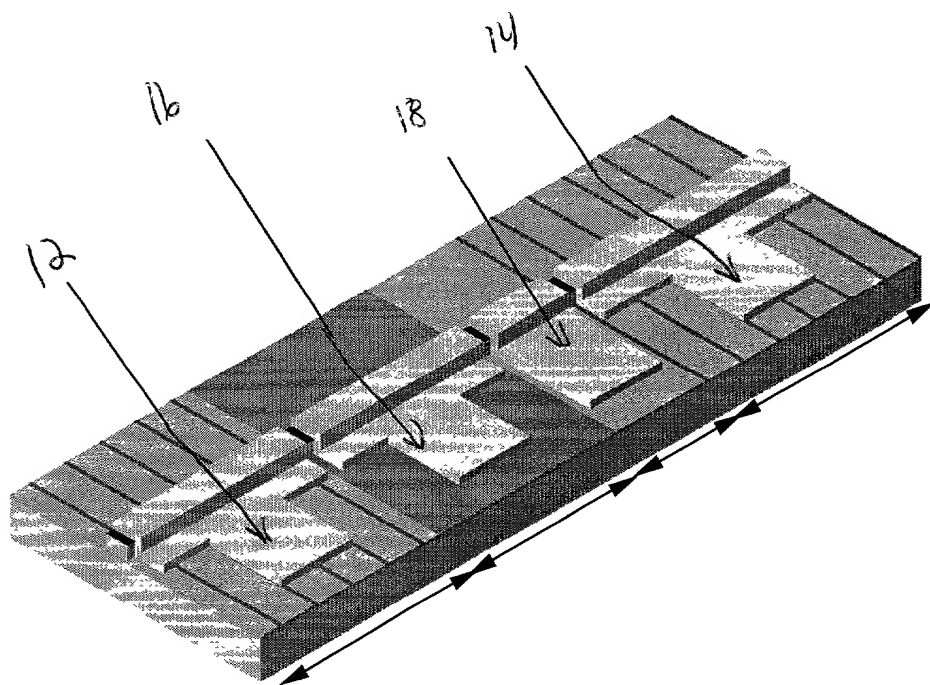


Fig. 2

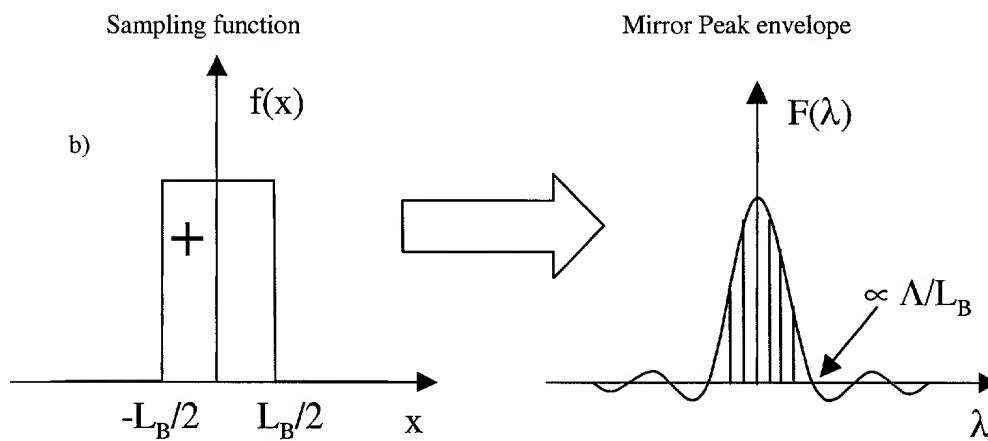
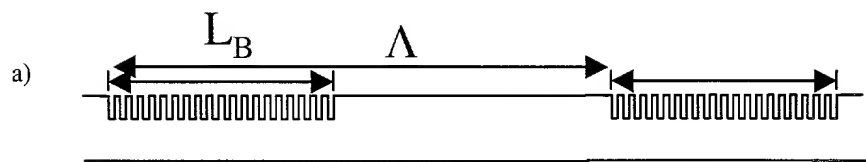


Fig. 3

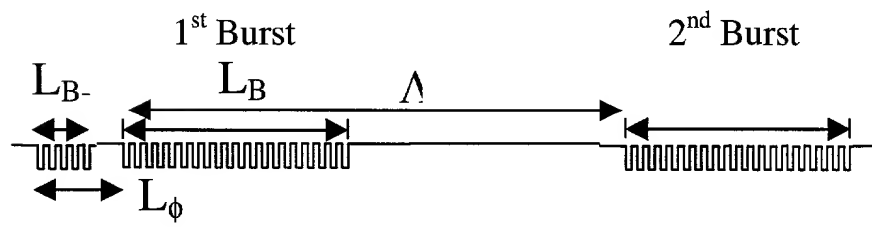


Fig. 4

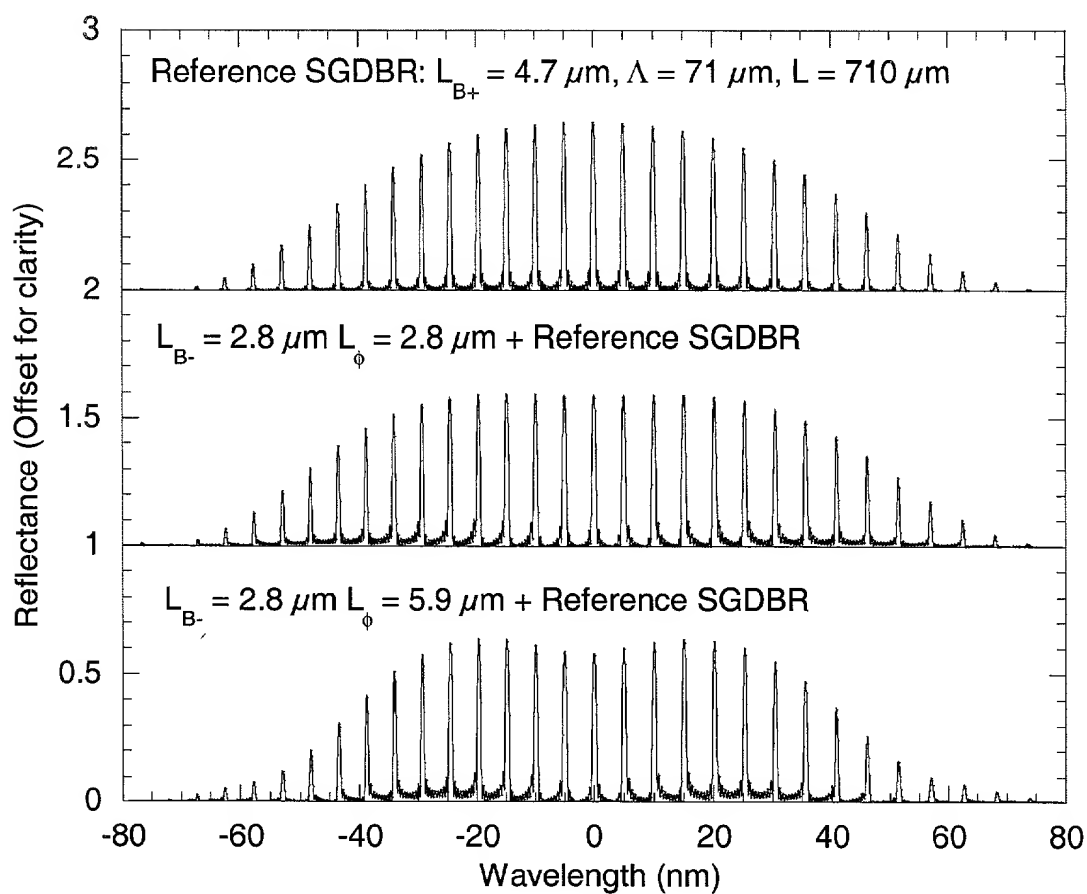


Fig. 5

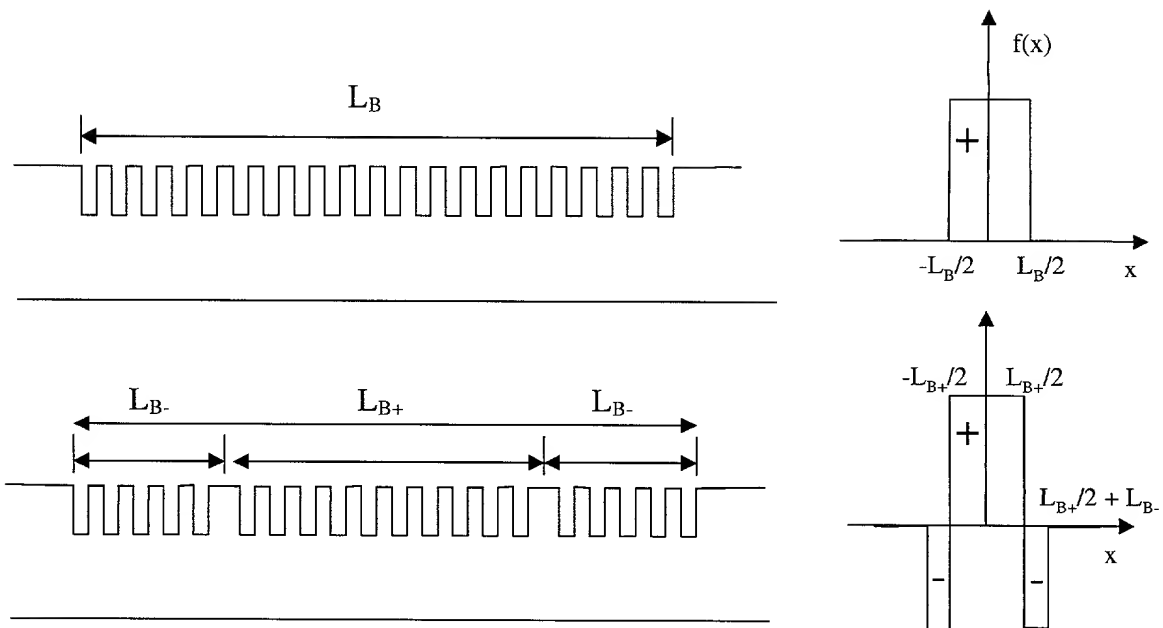


Fig. 6

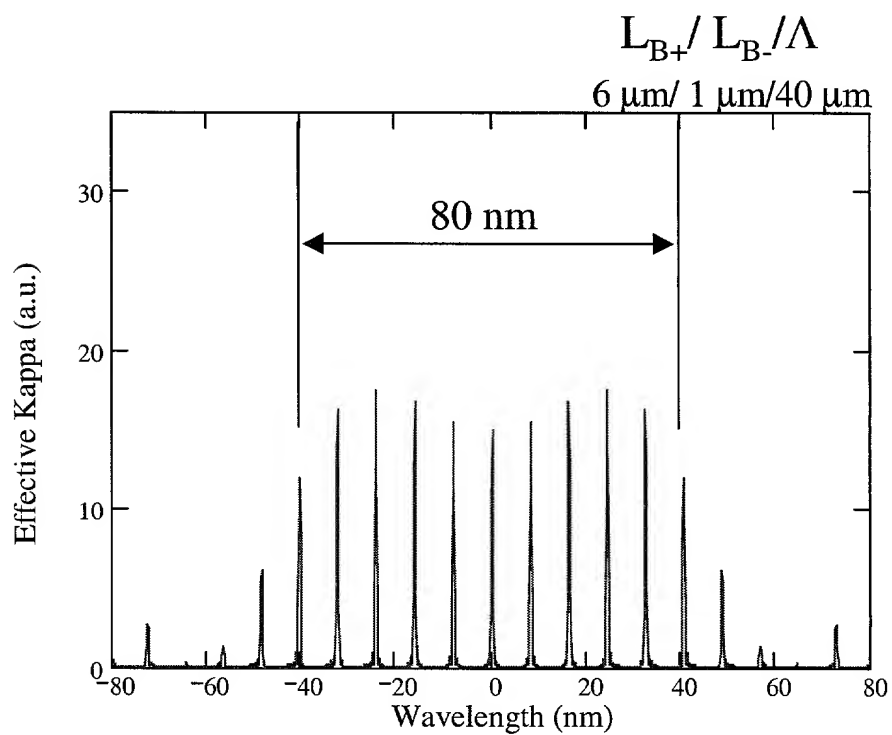
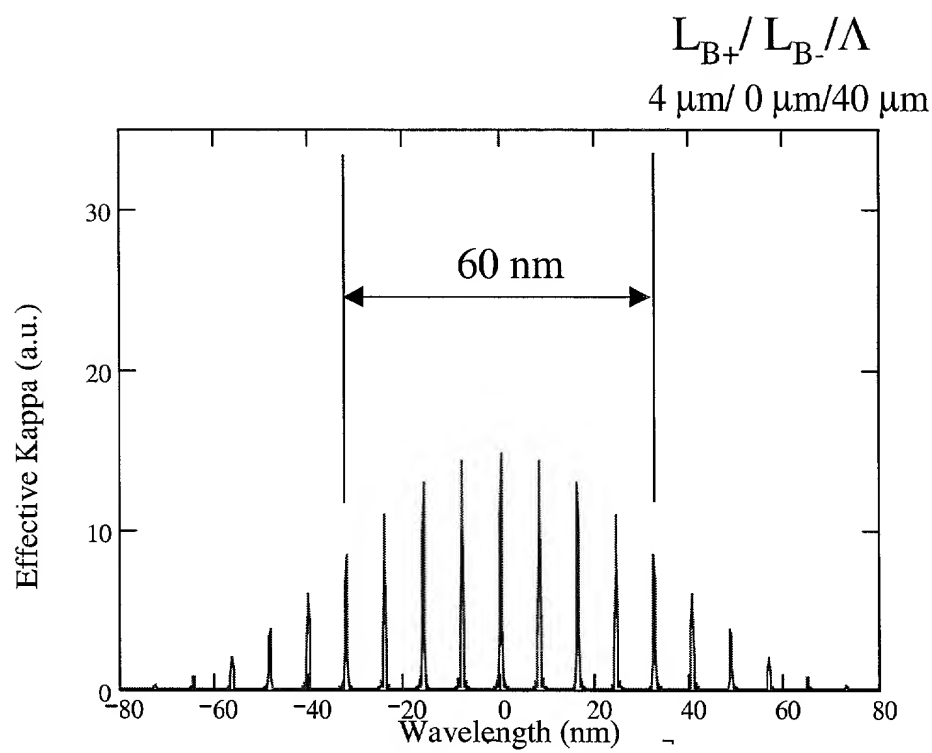


Fig. 7 a) & b)

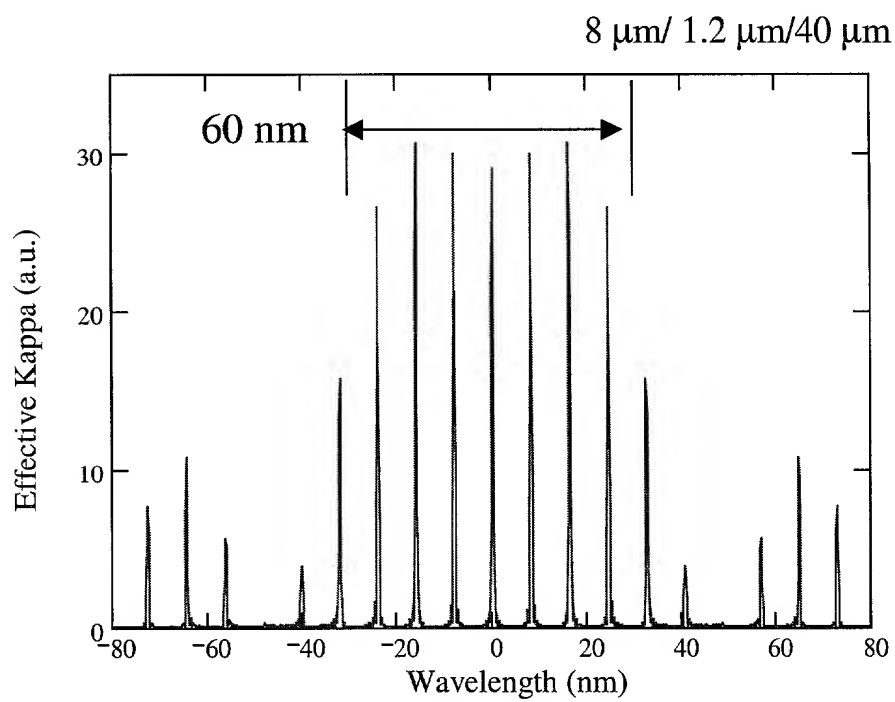
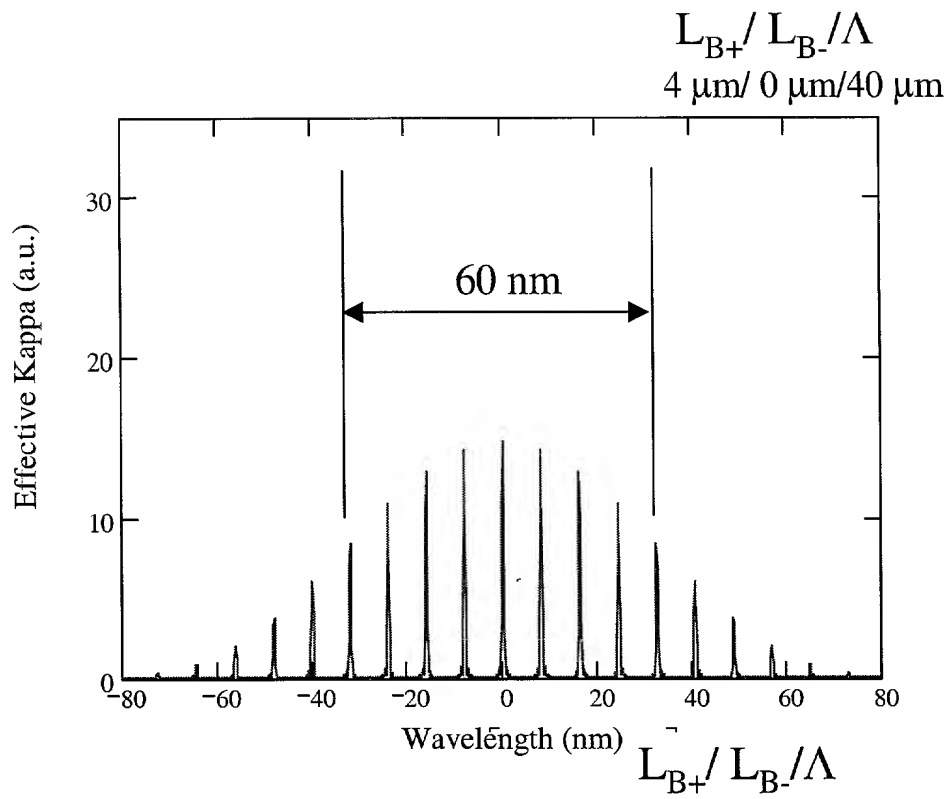


Fig. 8 a) & b)

Agility Communications, Inc.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

IMPROVED MANUFACTURABLE SAMPLED GRATING MIRRORS

The specification of which:

a. ☐ is attached hereto.

b. ☐ was filed on _____ as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT application having a filing date before that of the application on the basis of which priority is claimed:

a. ☒ no such applications have been filed.

b. ☐ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
OTHER FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or 365(c) of any PCT international application(s) designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose

material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. PARENT APPLICATION OR PCT PARENT NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)
60/210,612	09 June 00

I hereby appoint the following attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

Kenneth L. Stein

Registration No. 38,625

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Kenneth Stein to the contrary.

Please direct all correspondence in this case to Kenneth L. Stein at the address indicated below:

CUSTOMER NUMBER 27178

Kenneth L. Stein
C/o Agility Communications
600 Pine Ave.
Santa Barbara, CA 93117
(805) 879-9258

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

(1)	Full Name Of Inventor	Family Name Fish	First Given Name Gregory	Second Given Name A.
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	Post Office Address	Post Office Address 4716 Frazier Lane	City Santa Barbara	State & Zip Code/Country California 93110 / USA
Signature of Inventor(1):				Date:

(2)	Full Name Of Inventor	Family Name Coldren	First Given Name Larry	Second Given Name A.
	Residence & Citizenship	City Santa Barbara	State or Foreign Country California	Country of Citizenship USA
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Signature of Inventor(2):				Date:

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T.071.90 T.236.650

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) prior art cited in search reports of a foreign patent office in a counterpart application, and
- (2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

- (1) it establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
- (2) it refutes, or is inconsistent with, a position the applicant takes in:
 - (i) opposing an argument of unpatentability relied on by the Office, or
 - (ii) asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) each inventor named in the application:
- (2) each attorney or agent who prepares or prosecutes the application; and
- (3) every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

SMALL BUSINESS

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS
(37 C.F.R. 1.9(f) AND 1.27(c)) – SMALL BUSINESS CONCERN

I hereby declare that I am:

- ☐ the owner of the small business concern identified below:
☐ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN: Agility Communications, Inc.
ADDRESS OF CONCERN: 600 Pine Avenue, Suite A
Goleta, California 93117

I hereby declare that the above-identified small business concern qualifies as a small business as defined in 13 C.F.R. 121.801-805, and reproduced in 37 C.F.R. 1.9(d) for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled: **IMPROVED MANUFACTURABLE SAMPLED GRATING MIRRORS** by inventor(s) Gregory A. Fish and Larry A. Coldren described in:

☒ the specification filed herewith.

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37b C.F.R. 1.9(c) or by any concern which would not qualify as a small business concern under 37 C.F.R. 1.9(d) or a nonprofit organization under 37 C.F.R. 1.9(e). ***NOTE:** Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 C.F.R. 1.27)

NAME	_____
ADDRESS	_____
<input type="checkbox"/> INDIVIDUAL	<input type="checkbox"/> SMALL BUSINESS <input type="checkbox"/> NONPROFIT ORGANIZATION
NAME	_____
ADDRESS	_____
<input type="checkbox"/> INDIVIDUAL	<input type="checkbox"/> SMALL BUSINESS <input type="checkbox"/> NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as small entity is no longer appropriate. (37 C.F.R. 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereof, or any patent to which this verified statement is directed.

NAME:
TITLE:

ADDRESS: 600 Pine Avenue, Suite A
Goleta, California 93117

SIGNATURE: _____ DATE: _____

Express Mail No. ET103178994US

Agility Communications

Our Reference: